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STATUS REPORT ON THE FLUIDIZED BED INCINERATION SYSTEM FOR U. S. DEPARTMENT OF ENERGY DEFENSE WASTE JULY - DECEMBER 1976

Lewis L. Richey

Peter T. Faccini

Pen K. Feng

Chemistry Research and Development
PILOT PLANT DEVELOPMENT

Rockwell International

Atomics International Division
Rocky Flats Plant
P.O. Box 464
Golden, Colorado 80401

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SUBJECT DESCRIPTORS

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Incinerators
Waste Management

ROCKWELL INTERNATIONAL
ATOMICS INTERNATIONAL DIVISION
ROCKY FLATS PLANT
P.O. BOX 464
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STATUS REPORT ON THE FLUIDIZED BED INCINERATION SYSTEM FOR U. S. DEPARTMENT OF ENERGY DEFENSE WASTE JULY - DECEMBER 1976

Lewis L. Richey, Peter T. Faccini, and Pen K. Feng

Abstract. A fluidized-bed incineration facility has been designed for installation at the Rocky Flats Plant. The purpose is to develop and demonstrate the process for the combustion of transuranic waste. The unit capacity will be about 82 kg/hr of combustible waste. The combustion process will utilize *in situ* neutralization of acid gases generated in the process. The equipment design is based on data generated on a pilot scale unit and represents a scale-up factor of nine. Title II engineering is complete and construction work has begun.

INTRODUCTION

Through the years, operation of plutonium recovery facilities at the Rocky Flats Plant has resulted in the identifying of a need for an improved incineration system for combustible transuranic wastes. The conventional methods employed at Rocky Flats, though effective, have resulted in substantial maintenance problems because of equipment corrosion, short refractory life, and mechanical problems. In addition to frequent maintenance requirements, the process utilizes an aqueous flue-gas scrubbing system that requires additional treatment and increases the total plant waste volume. Also, the conventional open-flame incinerator produces a high-temperature (850 to 1000 °C), refractory-type plutonium dioxide that does not readily lend itself to the plant's aqueous recovery technique. The fluidized bed incinerator was conceived in 1971 as an alternative to the present conventional system.

The fluidized bed concept is being pursued through three channels of activity at the present time: (1) a 9 kg/hr (20 lb/hr) pilot plant system is undergoing operational testing with low concentrations of plutonium-contaminated solid and liquid wastes, (2) 82 kg/hr (180 lb/hr) developmental plant has been designed and is being installed in an existing building, and (3) an integrated laboratory development program is underway to provide specific and timely data for the larger systems. This substantial amount of research is being expended in an effort to not only overcome inherent problems in conventional incineration of transuranic wastes but also to develop an improved incineration system for processing existing or future waste from nuclear industry in general.

The fluidized bed process incorporates three concepts that set it apart from conventional incineration. One unique concept is the *in situ* neutralization of acid gases that are produced when materials such as polyvinyl chloride plastic are burned. Another is the use of a catalytic afterburner; the third is non-flaming, low-temperature combustion throughout the system. These three features are responsible for several advantages of this process over conventional methods. The most significant benefits derived are the elimination of refractory lined equipment, elimination of aqueous flue gas scrubbing, and minimization of equipment corrosion. These factors are expected to extend equipment life, decrease maintenance requirements, and improve overall waste-volume reduction.

SUMMARY

A fluidized bed incineration system has been designed for combustion of transuranic waste. The facility is designed for a capacity of about 82 kg/hr (180 lbs/hr), which will correspond to a heat release rate of about 1,600,000 kJ/hr (1,500,000 Btu/hr). The process equipment design is based on data generated in the pilot plant, and it represents a scale factor of nine based on solid-waste feed rates. Approximately 45% of the heat of combustion will be extracted through the walls of the afterburner by a water-spray cooling system. In the pilot unit, most of the heat is removed as sensible heat of the combustion products. A water-cooled heat exchanger in the flue gas stream will be used to remove approximately 55% of the heat of combustion from the process. In the pilot unit, the flue gas was cooled by dilution with room air. An air jet ejector was used in the pilot unit whereas high speed blowers will be used in the larger unit to provide motive force for gas flow through the process.

Title II engineering is complete on installation of the containment walls; the exhaust plenum and construction is 64% complete. Title II engineering also is complete, except for the air classifier on the process equipment portion of the project, and construction has begun. The project schedule has been adjusted to keep the cost in FY 1976 and FY 1976A within available funding limits. The projected start-up is in the third quarter of FY 1978.

An air classification system is being redesigned into the incineration facility for the removal of tramp metal from combustible waste. The hand sorted waste will be shredded and fed directly to the air classifier. The classifier will remove "tramp" metal, and the combustibles will pass through a second stage of shredding prior to introduction to the primary reactor.

To remove trace amounts of tramp metal that gets into the primary fluidized bed, a discharge screw has been tested on a bench scale and scaled up for the demonstration unit. The screw will remove the more dense metal particles without removing the bed material.

To overcome some operational problems with the preheater used on the pilot-plant fluidized-bed system, laboratory-scale tests were conducted on a new preheat system. The operational problems involved uneven heating in the catalyst preheater. This caused hot spots and degradation of the catalyst. Also, using kerosene as a fuel resulted in erratic ignition temperatures, which contributed to temperature control problems. To eliminate these problems, the catalyst was changed from a chromic oxide on a granular alumina support to platinum metal on an aluminum honeycomb matrix support. The larger void volume of this system resulted in better mixing of the fuel and air, and more uniform heating was accomplished. Erratic ignition still continued so the fuel was changed from kerosene to methyl alcohol. The tests produced better results than the present operating system, and methyl alcohol was found to be a better fuel than kerosene.

The process monitoring and control system has been better defined, and efforts are being directed toward completing the software configuration. A remote weighing station is also under development to impose strict inventory control on the drums of waste processed. This system is scheduled to be operational in September 1977.

EXPERIMENTAL PROGRAM

Air Classifier

As stated in an earlier status report (RFP-2540, dated March 7, 1977), alternative methods of waste classification have been investigated. The air classifier installed on the pilot-plant scale fluidized bed had a tendency to plug, especially at high throughput rates. The conveyor belt that fed the air classifier was prone to slippage because of high dust loading of the shredded waste. To eliminate these problems, the air classifier was redesigned to reduce pluggage and eliminate the belt conveyor. The air classifier will now be positioned directly below the first shredder to accept the shredded feed directly. This change eliminates the belt conveyor and feed star valve.

The old air classifier also contained many sections for deflecting the shredded waste. The principle of operation was to cause sufficient turbulence to allow lighter material to separate from the more dense material; also to impact the shredded material on the deflecting surfaces. This impaction caused the more dense material to fall counter to the rising air flow and raised the lighter material out of the unit.

The unit operated satisfactorily when the shredded waste was roughly the same particle size and shape. Severe plugging occurred when some of the shredded pieces were ribbon shaped. Those pieces would wind around the feed star valve, preventing the feeding of additional material, and would combine with dense material until the unit was plugged. By placing the new air classifier directly beneath the shredder, the feed star valve can be eliminated. Also with only one deflection of the air flow, the tendency to plug is minimized. An additional feature of the new unit is a movable vane. The vane can be positioned to give the most efficient separation of dense and light particles. In the event of pluggage, this vane can be positioned to allow total discharge of the pluggage to a receiving glove box.

A unit with these features was tested on a laboratory scale. The tests proved successful and the unit was operated until enough information was generated to develop design criteria for a demonstration scale unit. The design criteria have been released to Engineering for detailed assembly drawings. This unit should be designed by March 1977, fabricated by May 1977, and installed by June 1977.

Sintered Metal Filter Housing

The design on the present pilot plant uses eight sintered metal filter housings, and each has an isolation valve. In operation, the isolation valve on the filter housing to be blown back is closed, and high pressure air is used to knock the ash fines from the filter. As the process is scaled up by a factor of nine, this method becomes expensive to duplicate because of the large number of high-temperature, resistant, isolation valves required. To reduce costs on this project, the design was changed to an industrial type filter housing. This process will use two filter housings because of space and configuration limitations. Each filter housing will contain 96 sintered metal filter tubes that are one inch in diameter and approximately four feet long. They are arranged in 11 rows with each row having its own blow-back header. Each blow-back header has a low-temperature service selenoid valve to control the duration of the blow-back pulse. In operation, each blow-back header will pulse its associated filter tubes 0.25 second every 22 minutes. For each filter housing containing 11 rows of filter tubes, the blow-back header will be sequentially pulsed every two minutes.

To assure successful operation of this unit, bench scale tests were conducted to determine the size of the blow-back header, pulse duration, and pulse interval. To obtain visual observation of this operation, a one-inch diameter sintered metal tube was placed inside a vertical six-inch diameter glass pipe. Dust was then loaded on the sintered metal tube at the design gas flow rate through a single tube. To remove the collected dust, a pulse of high pressure air was directed down the tube without stopping the flow discharging from the system. The tests indicated satisfactory dust removal could be accomplished with this system. Design criteria were generated for this system and were tailored to the requirements for the demonstration scale plant. The two filter housing units have been fabricated and are in storage awaiting installation.

Primary Reactor Discharge Screw

In the pilot-scale fluidized bed system, hand sorting and air classification are used as pretreatment methods for removing tramp metal from the waste feed. As efficient as the air classifier is, trace amounts of tramp metal enters the primary reactor and accumulates in the bottom of the fluidized bed. A conceptual design has been completed for a device to remove tramp metal from the bed without removing the sodium carbonate bed material. The concept utilizes a screw conveyor to remove the tramp metal from the bed. A gas flow countercurrent to the conveyor discharge retains the sodium carbonate in the fluidized bed. To test how functional this concept is, a bench scale test was conducted using a two-inch diameter screw conveyor running through the bottom of a fluidized bed of sodium carbonate. The tramp metal added to the fluidized bed was carried out by the rotation of the screw while the countercurrent air flow segregated and retained the sodium carbonate in the bed. Tests have generated design criteria for a unit large enough to handle anticipated requirements. The unit is scheduled to be fabricated by August 1977 and installed by September 1978.

Fluidized Bed Preheat System

To start incineration, the fluidized bed must be raised with heated air to operating temperature. The present system on the pilot scale unit uses electrical preheat and catalyzed fuel heating to raise the ambient fluidizing air to about 600 °C. The catalyzed fuel heater is a fixed bed of chromic oxide on an alumina substrate. Heated air from the electric heater is mixed with fuel in this substrate. In operation, local hot spots develop in the fuel heaters. This causes uneven combustion and degradation of the catalyst. To overcome these problems, tests were made on a laboratory scale system in which an electric preheater is used to raise the ambient air to about 300 °C. This heated air stream is transported to another vessel. There, fuel is injected by means of a pneumatic atomizing nozzle into a matrix of catalytic platinum on alumina substrate. The matrix has more void volume and promotes better mixing than the fixed catalytic bed, thus eliminating local hot spots. After tests with kerosene as the fuel gave inconsistent results, methyl alcohol was tested. The methyl alcohol markedly improved the performance of the system by the new fuel's uniformity of ignition and combustion. Based on these results, a fueled preheat system using methyl alcohol was designed for the catalytic afterburner fluidized bed. Although the primary reactor must also be preheated, it is smaller, and electric air heating only will be used to raise the temperature of the primary bed to operating conditions. The fueled preheat system is scheduled to be fabricated by June 1977 for installation by September 1977.

PLANT DESIGN

Process Description

The fluidized-bed incineration process is basically the same for both the pilot plant unit now in operation and the developmental scale unit now under construction. The process used in the developmental unit will vary somewhat from that of the pilot plant in the method of heat removal and motive force for gas flow through the system. In the pilot plant, the heat of combustion is removed by blending the hot flue gas with a large amount of room air as it exhausts from the system. This method becomes impractical when the process is scaled up by a factor of nine for the development plant; consequently, the latter unit will be equipped with a water-cooled heat exchanger for flue gas cooling. For motive force, the development unit will utilize high speed blowers to replace the air jet ejector that is used in the pilot plant system. These process modifications will reduce both equipment and operating costs of the developmental unit relative to a scaled-up pilot plant system. A flow diagram of the development unit is presented in Figure 1.

The fluidized-bed incineration process for radioactive waste differs considerably from conventional incineration techniques. The current process involves the entire operation being carried out within a canyon and glove-box system for containment of radioactive contamination. Waste will be received in 0.2 cubic meter (55-gallon) drums. The waste is first passed through an air lock into a feed preparation glove box where it is hand sorted for removal of large size tramp metal. Sorted combustibles are then fed into a low-speed, cutter type shredder for coarse shredding. Small pieces of tramp metal that were undetected by hand sorting are shredded along with the combustibles. Coarse shredded material passes through an air classifier for removal of most of the remaining tramp metal. Metal separated by the classifier falls into a glove box where it can be bagged out for disposal. The waste containing trace amounts of metal is penumatically transferred into a second shredder for final sizing prior to incineration.

A constant pitch tapered screw feeds the shredded waste from the second shredder into a primary reactor of heated sodium carbonate (Na_2CO_3) granules. The granules are fluidized by a flow of compressed air and nitrogen gas. Within the hot fluidized bed, the waste is decomposed by partial combustion and pyrolysis, which produces sufficient heat to maintain a bed temperature of 550 °C. The air-nitrogen ratio of the fluidization gas is adjusted to promote the desired amount of combustion without open flame burning. Within the fluidized bed of Na_2CO_3, *in situ* neutralization of acid gases is accomplished. Neutralization is achieved rapidly when nascent hydrogen chloride gas (HCl), formed during the decomposition of polyvinyl chloride (PVC) plastic, reacts with Na_2CO_3 bed materials to produce sodium chloride (NaCl), carbon dioxide gas (CO_2), and water vapor. Offgas from the primary reactor passes into a cyclone separator

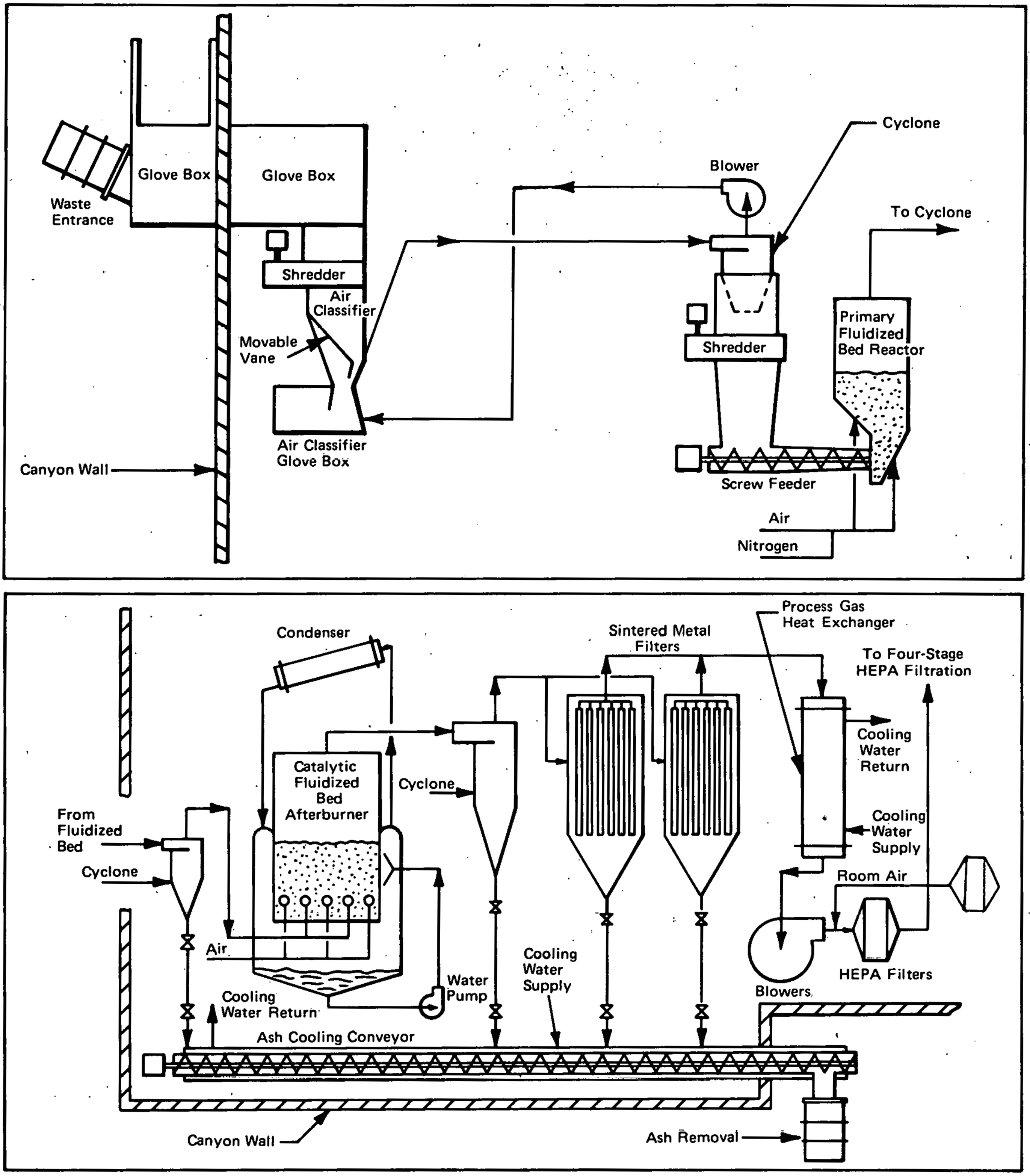

FIGURE 1. Flow Diagram of Fluidized Bed Incineration System for Transuranic Waste

where most of the entrained Na_2CO_3, NaCl, and fly ash is removed before the gas is introduced into the catalytic afterburner. It is in this afterburner that complete combustion is achieved.

Flue gas leaving the catalytic afterburner contains fly ash, catalyst dust, and small amounts of Na_2CO_3 and NaCl fines that were not removed from the primary reactor offgas by cyclone separation. About 75 to 85 percent of this dust is removed by passing the gas stream through a second cyclone separator. The remainder is removed as the gas passes through a bank of sintered metal filters prior to cooling to 50 °C in a water-cooled heat exchanger. The cooled flue gas is then pulled into four high-speed blowers that provide motive force for the process flow and that maintain a slightly negative pressure throughout the system. Offgas from the process passes through a bank of high efficiency particulate air (HEPA) backup filters prior to exiting through the building plenum system of four-stage HEPA filtration. Dust removed by cyclone separation and sintered metal filtration is cooled in a screw conveyor that transfers the residue into a drum for disposal.

The development plant will feature automatic control systems to regulate bed temperatures within the primary reactor and catalytic afterburner. The primary bed temperature will be controlled by the air-to-nitrogen ratio of the fluidization gas. A drop in bed temperature will activate automatic controls to increase the percent of air until the bed temperature climbs to the desired set point. Conversely, the percent of nitrogen will automatically be increased if a heat spike drives the bed temperature above a predetermined point. Catalytic afterburner temperature will be regulated by the quantity of waste being fed into the system. Deviations in catalyst bed temperature will prompt automatic controls to increase or decrease the speed at which the screw feeder transfers waste into the primary reactor. In this manner, the amount of fuel entering the afterburner will be controlled to maintain a preset catalyst bed temperature.

Status of Engineering Work

The installation of the fluid bed incinerator was split into two phases: Phase I, building modifications; and Phase II, equipment installation. Phase I work is being done by a local contractor and Phase II work will be done by Rockwell Maintenance.

Because of funding and manpower limitations, the construction phase (I) was also split into two parts. Phase IA includes the removal of existing ducts and piping, installation of the four-stage exhaust filter plenum and associated exhaust ducts, and the installation of conduit for the main electrical feeder lines. This portion of the design was completed, reviewed, and submitted to the local ERDA (now DOE) construction coordinator on May 14, 1976. The local construction company began work the following month.

Phase IB involves erection of block walls and doors and installation of the motor control station, main electrical feeder lines, and the lighting and fire sprinkler systems. This portion of the design was completed, reviewed, and submitted to the local ERDA construction coordinator on August 9, 1976. The Phase IB package was then added to the Phase IA work. As of December 31, 1976, the local construction company was 64 percent complete with the Phase I work. The work was scheduled for 72 percent completion but a change in contractor was made on November 12, 1976. Work was resumed on December 22, 1976. It is estimated that the Phase I work will be complete by April 1977.

Design of process equipment and associated process piping is complete except for the air classifier, which is scheduled to be complete in March 1977. A title II review of the remaining equipment was held November 30, 1976. Comments at that review have been incorporated into the package, and the package has been released to Chemistry R&D.

The ordering of major pieces of equipment is continuing on schedule. Table I represents the order placement data and delivery date for major equipment items. Materials required for equipment installation will be purchased when installation begins in FY 1977. The analytical equipment for detecting carbon monoxide, carbon dioxide, oxygen, hydrogen chloride, and water vapor in the process offgas stream will be purchased in FY 1977.

TABLE 1. Placement and Delivery Dates for Major Equipment Items

Item	Order Placement Date	Delivery Date
Hydraulic Shredders	7-11-75	Delivered
Cyclones	3-12-76	Delivered
Air Classifier	3-20-77	5-31-77
Exhaust Blowers	3-22-76	Delivered
Entry and Sorting Glove Box	6-15-76	1-15-77
HEPA Filter Housing	6-24-76	Delivered
Sintered Metal Filter Housing	6-28-76	Delivered
Feed Screw	7-30-76	5-01-77
Process Gas Heat Exchanger	9-22-76	3-28-77
Condenser	10-01-76	3-14-77
Ash Cooling Screw	10-01-76	4-15-77
Catalytic Fluidized Bed	10-01-76	5-20-77
Primary Fluidized Bed	11-22-76	3-08-77

Process Monitoring and Control Systems

A sophisticated process monitoring, control, and data evaluation system is planned for the fluidized bed incinerator. A programmable data processor-11/10 (PDP-11/10) minicomputer will control the process and will analyze pertinent data. The Foxboro Interspec system will be the communications link between the computer and the Foxboro Spec 200 input/output (I/O) modules.

A simplified hardware configuration is shown in Figure 2. In the diagram, process measurements are divided into two groups. Those measurements associated with process control are converted to 0 to 10 volt signals proportional to the measured value in the Spec 200 input modules. They then go to a controller and to the Foxboro Interspec Controller Communication Module (CCM) where analog-to-digital signal conversion occurs. Process measurements not associated with control loops are converted to 0 to 10 volt signals proportional to the measured value in the Spec 200 input modules. These signals then go to the Foxboro Interspec Analog Input Modules (AIM) where analog-to-digital signal conversion occurs. All digital signals are then transferred via a serial communications bus to the Foxboro Universal Interspec Communications Module (UISCM) and to the Digital Equipment Corporation (DEC) PDP-11/10 unibus. The signals received by the PDP-11/10 are stored on the Remex Flexible Diskette System, converted to engineering values, and displayed on the cathode ray tube (CRT) and the Graphics Display Panel. Incoming signals also are checked for alarm status and are checked against previously received signals to determine a rate of change for each measurement. In a similar manner, signals generated by the PDP-11/10 for correcting the controlled variables travel via the PDP-11/10 unibus, UISCM, serial communications bus, CCM, Spec 200 output modules, and to the final control devices.

In the control loops, the controllers mode of set point operation in the CCM may be automatic, manual, or computer controlled. With these options, the operator can make adjustments to the control system in the local automatic or manual mode as a back-up for computer control.

This incineration process has 10 control loops for the adjustment of critical flows, pressures, and temperatures, and 53 process measurements for monitoring 26 temperatures, 16 pressures, 5 flows, 4 weights, and 2 contact closures. The Foxboro CCM has a capacity of handling 16 control loops, and each Foxboro AIM can receive 48 input signals. The Foxboro Interspec system can, therefore, accommodate an additional 6 control loops and 43 process measurements with minor hardware additions.

Software for this sytem will be oriented for a real-time computer controlled process. The software will control the transfer of all process sensor data into a process data base. Data handling routines will access and transfer information between peripheral devices and the PDP-11/10 minicomputer. Peripheral devices are the Foxboro Interspec system, process graphics display panel, Remex Flexible Diskette system, CRT terminal, and the Remote Weighing station (RWS).

All peripheral devices are vendor supplied items except the RWS. This device is being developed to impose strict inventory control on drums containing radioactively contaminated feed material. In the operating sequence for this unit, the RWS will accept a drum identification code from the operator and check it against a master unprocessed drum list. If the drum code is on this list, the RWS will accept

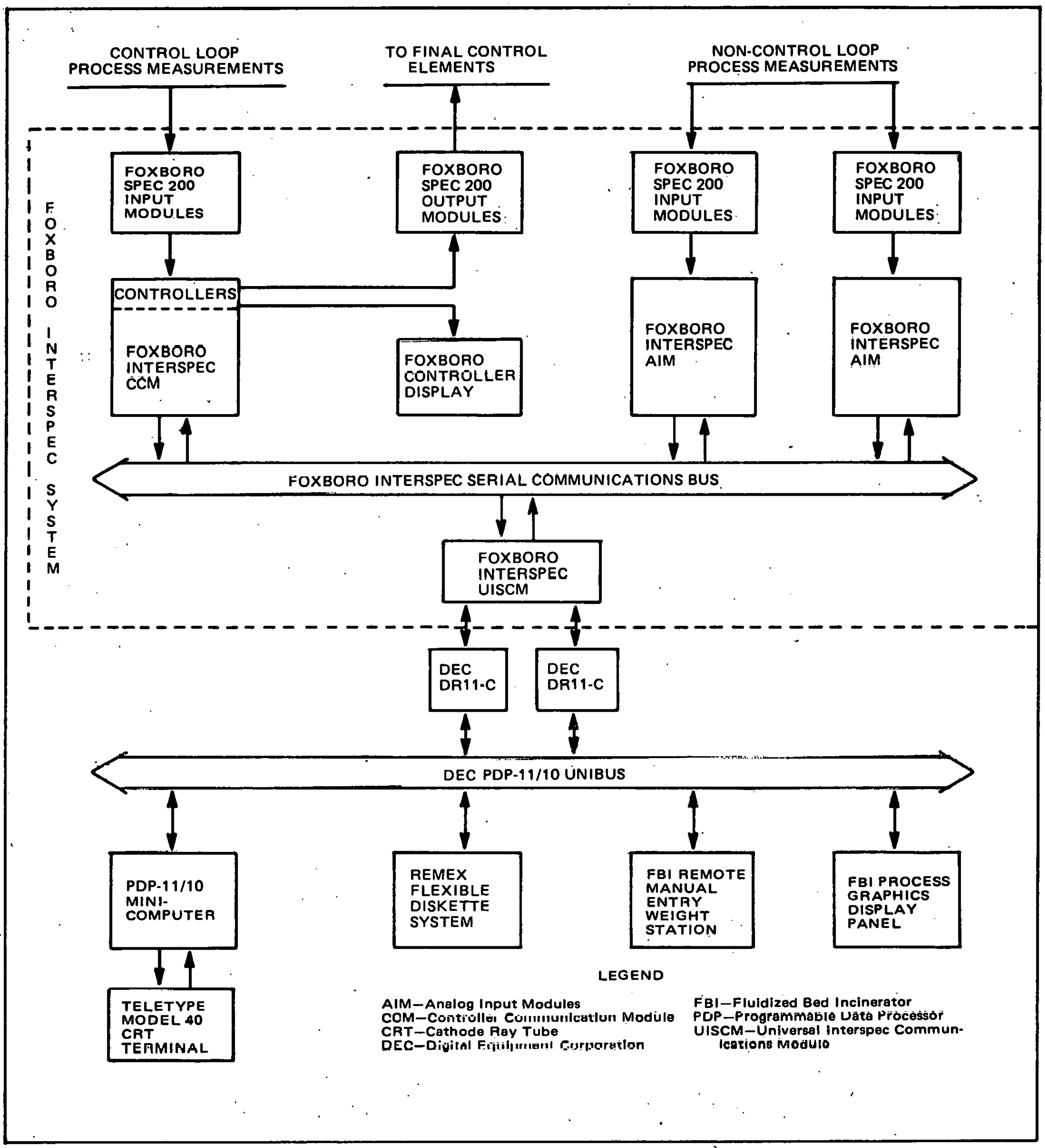

FIGURE 2: Hardware Configuration for Process Monitoring and Control System

the gross weight of the drum as it is hoisted to the entry glove box. A load cell located in the drum-lift hoist will acquire the gross weight and transmit this value to the RWS. The RWS, having detected the movement of the load to the entry glove box, will acquire the weight and check for overweight readings. When the load is detected moving down to ground level, the RWS acquires a tare weight and substracts it from the gross reading to get a net weight. After the operator transmits the processed drum code and associated net weight to the PDP-11/10 minicomputer, the RWS is ready to start this sequence again. As each drum is processed, the drum identification number is removed from the master unprocessed list and appended to the processed drum list. Any deviation in this sequence will abort acquisition of the data. The operator must determine the malfunction, correct the error, and reinitiate the operating sequence.

Programming of the PDP-11/10 minicomputer is continuing with an off-line, steady-state heat and material balance using Fortran IV. The program will use process data stored on the Remex Flexible Diskette system after completion of each experimental test. Analysis of the performance of many operating units (condenser, heat exchangers, reactors) will provide engineering designers with information on those variables pertinent to scale-up designs, process control, and process optimization.

Present capabilities of the program will include the following:

1. A total process heat and material balance.

2. Component mass balances for various process variables on some process units.

3. Pressure, temperature, and velocity profiles throughout the process.

4. Determining the heating value of the feed material.

Additionally, the PDP-11/10 minicomputer is presently being used to monitor the scheduling and cost of vendor-supplied equipment and material items.

Work accomplished during this period is divided into two areas:

1. Hardware
   a. The Foxboro Interspec System has been specified and placed on order.
   b. A control panel and console for the controllers has been designed and placed on order.
   c. Interfacing computer cards for connecting the Foxboro System to the DEC PDP-11/10 minicomputer are on order.
   d. Ninety percent of the process sensors, including thermocouples, pressure cells, flow meters, weighing scales, analytical instruments, and final control devices have been delivered.
2. Software
   a. Heat and material balance programming is 90% complete.
   b. Process data base development and data handling routines for the PDP-11/10 minicomputer and peripheral devices is 20% complete.
   c. The equipment inventory and cost control program is complete and in use.

To complete the process monitoring and control system, the following tasks must be accomplished:

1. Hardware
   a. Delivery of the Foxboro Interspec System and interfacing computer cards.
   b. Specifications, ordering, and delivery of the process graphics display panel and remote weighing station.
   c. Installation, wiring, and testing of all process instrumentation and final control devices.
2. Software
   a. Completion of the total process heat and material balance.

b. Completion of the data base architecture and data handling routines.

c. Modify the data acquisition program to include controllers set point and process optimization calculations.

d. Generate a complete set of diagnostic routines for troubleshooting and repair of the Foxboro Interspec System.

e. Document all software routines and prepare a process control instruction manual.

f. Indoctrinate and train operating personnel.

CONCLUSIONS

1. Bench-scale tests indicate that a new air classifier will improve the performance of the pretreatment equipment.

2. The redesigned sintered metal filter housing will reduce equipment costs without sacrificing performance.

3. Trace amounts of metal that get into the primary reactor can be removed automatically by a recently designed and tested discharge screw.

4. Design changes in the equipment for preheating the fluidized beds has eliminated some problems.

5. A change in construction contractors will most likely delay the projected start-up by 30 to 45 days.

6. Purchase of process sensors and computer related hardware is proceeding on schedule.